

GUIDELINES FOR TRANSFORMATION BETWEEN LOCAL AND GLOBAL DATUMS

Introduction

Positions used for spatial data (latitude & longitude, also expressed as a grid coordinates) are the realisation of a reference surface known as the geodetic datum. The datum usually consists of one or more origin stations and a best fitting model of the earth (an ellipsoid). Positions in terms of the locally adopted datum are propagated through the country, with varying degrees of accuracy, by survey networks. In the past datums were generally based on one or more astronomically determined positions and the best model of the earth for the local area. However, With modern technology, such as the Global Positioning System (GPS), global datums are now readily accessible.

The World Geodetic System 1984 ([WGS84](#)) is used by the US Department of Defense for GPS and is suitable for charting and navigation. The International Terrestrial Reference Frame ([ITRF](#)) is based on many GPS, Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI) stations worldwide and is recommended by the International Association of Geodesy & PCGIAP for regional datums and scientific applications ([Working Group 1 Resolution of 1999](#))

The difference between positions in terms of an individual local datum and positions in terms of a global datum may be of the order of several hundred metres, and may vary considerably even for a single local datum. If the local survey network has variable quality or does not have a continuous landmass, a country may effectively have a number of local datums, requiring a number of different transformations to the global datum.

With the increasing exchange of geographic information local and globally, positions need to be available in terms of both a local and global datums. The process of mathematically converting positions from one datum to the other is known as transformation.

Transforming Positions

There are a number of ways to mathematically transform positions from one datum to another, but they all require "common points". Common points are surveyed points that have known positions in terms of both the local and the global datum. The achievable accuracy of the datum transformation will be determined by the number, distribution and accuracy of these common points and the transformation technique adopted. Generally speaking, the greater the accuracy required, the more common points are needed.

The common points chosen should be a good sample of the true relationship between the local and global datums. If the local survey network was entirely consistent and regular and was merely offset from the global datum, a single

common point would be sufficient to determine this block shift. However, this is a highly unlikely scenario and the more irregular the local survey network, the more common points will be required. A good understanding of the local datum and survey framework is required before a datum transformation can be produced.

Obtaining Common Points

Ideally, global datum positions should be determined for the local datum origin points and the local survey network recomputed in terms of the global datum. Different locations could be used for the global positions, provided they were accurately connected to the survey network. After the re-computation, every point in the survey network would be a "common point" and, provided the new positions for the origin points were of suitable quality, would probably also give an improved survey network in terms of the global datum.

A re-computation of the survey network in terms of the global datum assumes that all the original observations are available, but this may not be the case. An alternative strategy would be to obtain sample common points at suitable existing survey network sites. These sites should be chosen to represent the characteristics of the network, so where the survey network is consistent only a few would be required, but where it is inconsistent, many more would be required. Of course any isolated areas (e.g. unconnected islands) would need their own set of common points. These common points are then be used to determine a transformation model for the other points in the survey network and the many derived spatial data sets that depend on the local datum but are not directly connected to the survey network.

It is wise to obtain far more than the minimum number of common points. The redundant points will give a much better idea of the consistency of the survey network and the derived transformation parameters. A number of the redundant common points ("check points") can be reserved from the initial transformation modelling and later can be used as an independent check of the quality of the transformation process, by comparing actual and transformed positions. If the difference between the actual and transformed positions (residuals) is not acceptable, then (i) the derivation of the transformation process can be repeated using a different selection of common points, or (ii) more common points can be obtained, or (iii) a different transformation method can be used.

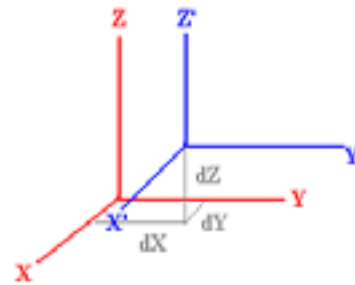
Transformation Methods

There are many ways of modelling the transformation between two datums, but those in commonly use include:

1. Molodenskys
2. 7-Parameter
3. Surface Fitting

1. Molodensky's Formulae

Molodensky's method is commonly used in hand-held GPS receivers and Geographic Information Systems (GIS). The formulae are simple, assuming that the transformation between the local and global datums can be represented by 5 parameters: a shift at the origin (the earth's centre of mass) along the earth-centred Cartesian coordinate axes (ΔX , ΔY , ΔZ); and the difference between the local and global ellipsoids (semi major axis and flattening). The origin shifts can be determined by an averaging of the same differences at each of the common points and the difference in ellipsoids is a simple subtraction of the ellipsoid parameters



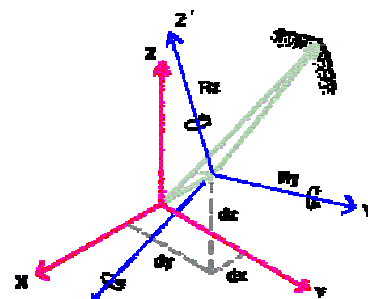
The United States Department of Defense WGS84 Technical report provides Molodensky parameters to transform between many local datums and WGS84. However, the data on which these parameters are based may be very limited and the parameters may have limited accuracy.

Although it depends on the data used, the best accuracy that could be expected from this method would be perhaps 5 metres.

| Molodensky Transformation | |
|--|---|
| <i>Advantages</i> | <i>Disadvantages</i> |
| <ul style="list-style-type: none"> • Simple derivation • Simple application • Available in GIS packages and hand-held GPS | <ul style="list-style-type: none"> • Assumes internally consistent networks • Limited accuracy • Derivation requires ellipsoidal heights |

2. 7-Parameter Transformation

The 7-parameter method assumes a similarity relationship between the local and global datums. The common points are used in a Least Squares process to solve for 7 parameters which represent the relationship between the two datums: origin shifts at the earth's centre of mass (ΔX , ΔY , ΔZ); rotations about each of the axes (R_x , R_y , R_z); and a scale change between the two systems. To be able to solve for these seven parameters a minimum of three common points are required,



but in fact many more are needed to reliably model the relationship. Even with many hundreds of common points, the results of a 7-parameter transformation may not be acceptable if the coordinates used are non-homogeneous. In this case, it may be possible to produce separate 7-parameter sets for sub-regions

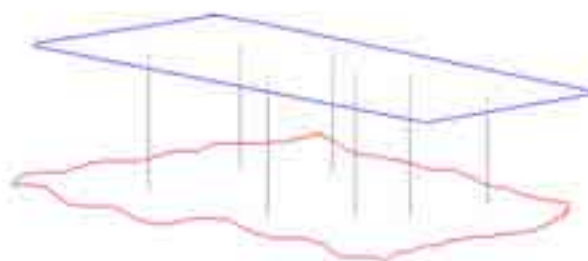
that are more consistent, but even this may not be satisfactory and for consistency, if not for accuracy, it may be necessary to use a more sophisticated method.

Again the accuracy of this method is limited by the data used, but the best that could typically be expected would be a metre or two.

| 7-Parameter Transformation | |
|--|---|
| <i>Advantages</i> | <i>Disadvantages</i> |
| <ul style="list-style-type: none"> • Improved accuracy • Used in many GIS packages | <ul style="list-style-type: none"> • Assumes consistent networks • Moderately complex derivation & application • Requires ellipsoidal heights for both local and global positions • Accuracy limited by network consistency |

3. Surface fitting

If the neither the Molodensky nor 7-parameter transformation methods are suitable it may be necessary to adopt a method that uses the difference in position at each common point to in effect fit a surface, which can then be used to interpolate the change for other points. This means that there will be a surface for the change in latitude, and another for the change in longitude.



Examples of this type of transformation are the Minimum Curvature method used in the USA (NadCon); the Multiple Regression method used in Canada; and the Collocation method used in Australia.

The Collocation method used in Australia caters for the datum transformation and also distortion in the local survey network, providing improved transformation for derived data sets. Where sufficient quality data has been used, transformation with an accuracy of better than 10 cm has been achieved ([Collier, 2002](#)).

Although initially mathematically complex, the results from this method can be presented to users as a simple file of shifts in terms of latitude & Longitude, on a regular grid, which can be used to interpolate the shifts for any other point. If this grid is provided in a well-accepted format (such as [NTv2](#)) the grid file can be immediately used in many GIS packages.

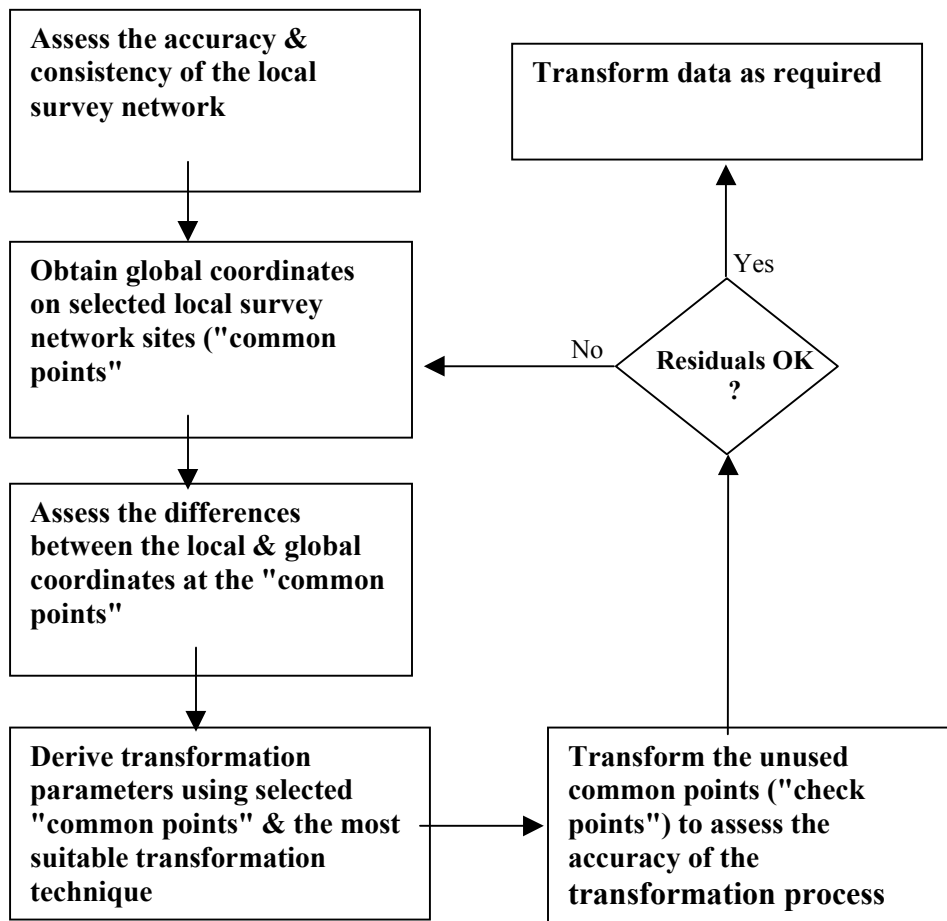
| Surface Fitting Transformation | |
|--|---|
| <i>Advantages</i> | <i>Disadvantages</i> |
| <ul style="list-style-type: none"> • Potentially very accurate • Simple user applications can be provided. • Easy to integrate into GIS systems | <ul style="list-style-type: none"> • Very complex to initially derive • Many common points needed |

Summary

The selection of a datum transformation method depends on the accuracy required and the number of common points available. For large consistent networks of a suitable standard, typical accuracies can be:

- Molodensky's formulae: 5 metres
- 7-parameter: 1-2 metres
- Surface fitting/Collocation: 0.1 metre.

General Transformation Procedure



Some Reading

Collier P., (2002), "[Development Of Australia's National GDA94 Transformation Grids](#)"

Harvey B.R. (1986) *Transformation of 3-D Coordinates*. The Australian Surveyor 32(2):105-125.

ICSM (2002), "[Geocentric Datum of Australia Technical Manual Version 2.2](#)"

Leick A., (1995), "[GPS Satellite Surveying](#)", 2nd Edition, John Wiley & Sons.

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Steed J.B., (1998), " Datum Transformation The Australian Experience", proceedings of the 4th PCGIAP meeting, Tehran, February 1998, National Cartographic Center of Iran, Iran